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# PROCEEDINGS

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# SURVEYING AND MAPPING FOR A HYDRO-ELECTRIC DEVELOPMENT

by D. J. Fraser and A. D. Hartwell

SURVEYING AND MAPPING DIVISION

*{Discussion open until October 1, 1955}*



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## THIS PAPER

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# SURVEYING AND MAPPING FOR A HYDRO-ELECTRIC DEVELOPMENT

D.J. Fraser[1] and A.D. Hartwell[2]

This paper was written primarily to describe the methods and procedures employed by the Pacific Gas and Electric Company in obtaining accurate surveys and maps of the proposed McCloud-Pit Hydro-Electric Development, when the time limit imposed to complete the work played an important role in the final results.

It is the opinion of the authors that the methods and procedures described could be used as a pattern for similar surveying and mapping problems.

The following report begins with the location and description of the area to be surveyed and mapped. The report then continues through the reconnaissance, aerial photography, triangulations, and the other necessary features and terminates with the final objective of accurate surveys and maps for a proposed hydro-electric development.

In Shasta and Siskiyou Counties, located in the north central part of the State of California, is the McCloud River and its tributaries. Rising on the slopes of Mt. Shasta and flowing in a southwesterly direction through a rugged mountainous country with deep canyons and heavy timber, the McCloud River eventually empties into Shasta Reservoir. This river has a large undeveloped power potential which when harnessed can help satisfy the ever increasing demands for power which parallel the growth of population and industry in California.

To pioneer, study, and finally arrive at a workable, economic plan for developing the McCloud River required a great deal of time, effort, and money. The management of the Pacific Gas and Electric Company authorized its engineers to perform the necessary investigation work to determine if the river had the required qualifications for a hydro-electric development.

Reliable maps are the first essential in planning a hydro-development. The only maps available of the area were U.S.G.S. Quadrangles and a Shasta National Forest Map. Both maps were drawn to a scale of two miles to the inch with a contour interval of 200 feet, which made them unsuitable for any detail work. They could only be used for the first preliminary layout and study.

To gain additional information, a reconnaissance party of four company engineers, along with two packers and a string of pack horses, started north from Shasta Lake during June, 1952. Their object was to obtain barometric elevations for profiles of the main river and some of its tributaries, estimate flows of side streams tributary to the main river, find potential damsites, and in general, get a visual idea of the country. Progress of the party was

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slow as there were no roads in the area and the trails had not been brushed for several years. The average progress was six miles a day. Twelve days were required to gain the information.

To obtain the necessary profiles, the party carried two precise Wallace and Tiernam Altimeters. Approximately sixty altimeter readings were made at numerous points along the stream that could be positively identified on a map.

As the company's Pit No. 5 Power House, located at the south end of the proposed development, would have approximately the same atmospheric conditions as those encountered on the reconnaissance trip, a Short and Mason recording micro-baragraph was set up at this point. Using the baragraph as a field base, the field readings were adjusted accordingly. As a check, field readings were made on several U.S.G.S. bench marks. The result showed the altimeter readings checked the U.S.G.S. elevations in all but one case by less than three feet. In the other reading there was a difference of nine feet.

In February, 1953, company engineers were authorized to obtain the necessary field and office information so that accurate exhibits could be submitted to the Federal Power Commission in an application for license to develop the project. January, 1954, was the date set for the final exhibits to be completed.

This program presented a problem because the area to be surveyed and mapped is mountainous, subject to severe storms and heavy snowfall, with only six to eight months of the year suitable for field work. It was impossible to put a sufficient number of survey crews into the field to accomplish the necessary work by conventional methods of ground surveys in the time limit imposed, so this method was dismissed and aerial methods adopted.

The area was photographed at a scale of one inch equals one thousand feet, using 8-1/4 inch focal length precision mapping cameras. An area of approximately three hundred and seventy-five square miles was covered by north and south flight lines. It took four hundred and seventy, nine inch by nine inch photographs to cover the area. The overlap in pictures was sixty per cent in line of flight and thirty per cent between flight lines. Two sets of prints were made from the negatives, one set being used by company engineers for stereoscopic studies, while the mapping was in progress. The other set was for field identification work and a set of glass depositives for the stereoscopic plotters used in mapping. The cost of the photography was $12.50 per square mile or about two cents an acre.

To map the area covering the presently proposed development required fifty five square miles of the three hundred and seventy five square miles photographed. The additional three hundred and twenty square miles was photographed to provide sufficient coverage for alternate plans of development if additional studies showed this to be advantageous.

After obtaining the pictures, the next major problem was to establish horizontal and vertical control on the ground with enough identification to properly orient the pictures. An attempt was made to mark control points on the ground prior to photography by using aluminum foil covered with chicken wire held in place with stakes. This method was soon abandoned because bears, which are numerous in this country, destroyed the control points before they could be used. The establishment of control points after the pictures had been made, required photogrammetists to go into the field and mark landmarks that could be identified on the pictures. These marks were correspondingly pinpointed and numbered on the photographs. Upon completion, a triangulation system was set up to tie these points to government bench marks and to a horizontal control system.

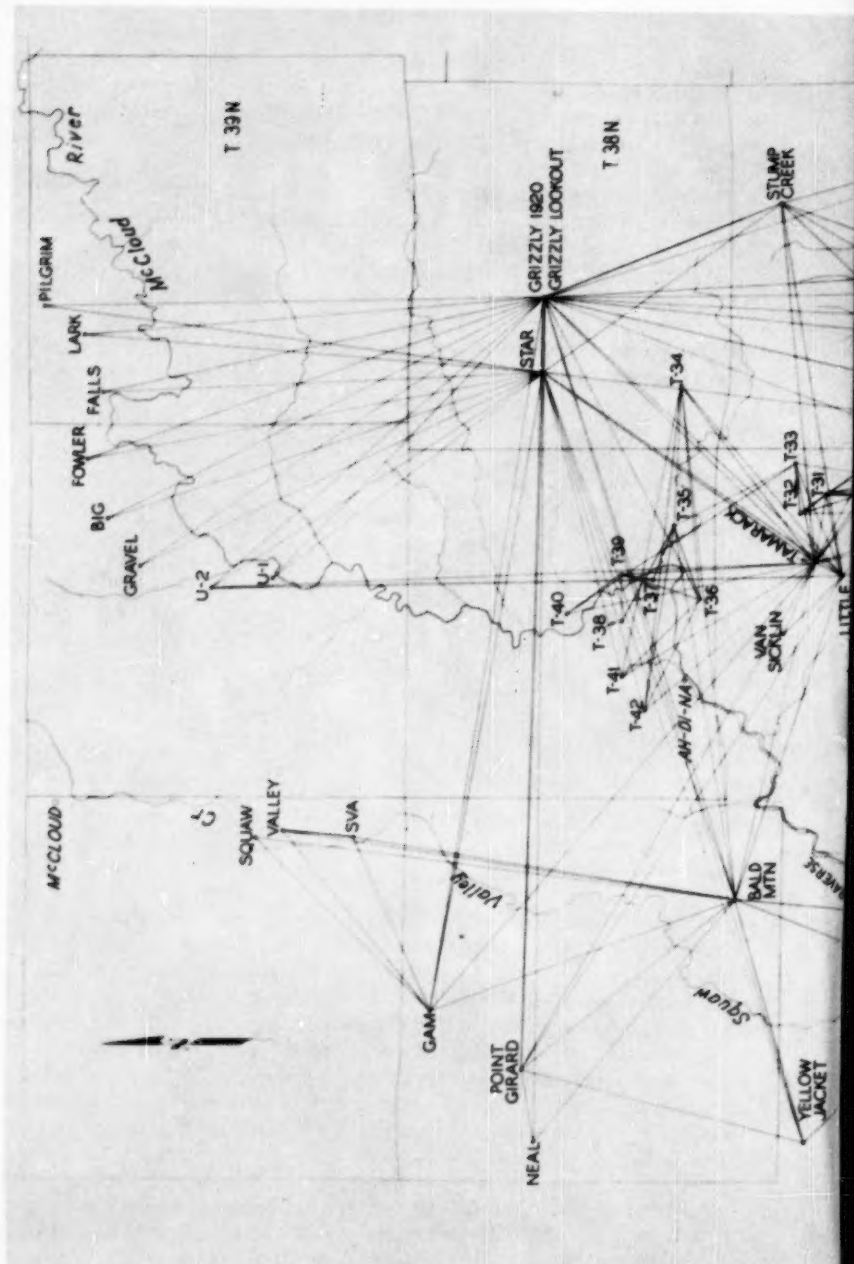
The start of the triangulation system was a base line on the company's existing Pit No. 5 tunnel. The bearing and coordinates of this line were used as a base for the entire survey. Due to the heavy stand of brush and timber, great difficulty was encountered in setting triangulation stations close to the general layout of the project. As a result, the highest points in the vicinity were used as a main base network from which smaller networks were established to tie in identification points. Using Kern Theodolites, that read to one second of arc and can be estimated to one tenth of a second, all horizontal angles were turned a minimum of eight times—twice in each of the four quadrants of the compass. The average angle was used, thereby eliminating chance of instrument errors. Vertical angles for trigonometric levels were turned a minimum of four times.

In establishing the main base network, a number of the stations used were triangulation stations set by various government agencies. Use of the information obtained from these stations acted as a good check on the new work. The following tabulation compares the data as furnished by the United States Forest Service and the corresponding data from this survey.

| THIS SURVEY | | U. S. F. S. | |
|---|---|---|---|
| Bagley Elev. 4380 | | Elev. 4378 | |
| N. 55° 41' 12" E. | 18,795 | N. 55° 41' 40" E. | 18,794 |
| Oak Mountain | | | |
| Big Bend Elev. 2423 | | Elev. 2421 | |
| N. 53° 06' 18" W. | 50,516 | N. 53° 06' 13" W. | 50,519 |
| Tamarack Elev. 5224 | | Elev. 5226 | |
| Oak Mountain | | | |
| N. 12° 21' 30" E. | 25,312 | N. 12° 22' 20" E. | 25,315 |
| Stump Creek Elev. 4122 | | Elev. 4126 | |
| North Fork | | | |
| N. 37° 55' 48" E. | 59,399 | N. 37° 53' 45" E. | 59,400 |
| Grizzly 1920 Elev. 6251 | | Elev. 6253 | |
| Grizzly 1920 Elev. 6251 | | Elev. 6253 | |
| S. 22° 25' 21" E. | 21,180 | S. 22° 24' 42" E. | 21,177 |
| Stump Creek Elev. 4122 | | Elev. 4126 | |

It was not until the triangulation system had reached the upper extremities of the project that a suitable check base line could be established. The triangulation network consisted of over one hundred and sixty triangles that had been computed, adjusted, and balanced before closure on a six thousand foot baseline could be made. The closure was less than two feet. Figure 1 shows the magnitude of the triangulation network. The bearing check was twenty-seven seconds on solar observations adjusted for the convergence of meridian. This accuracy was better than expected, due to handicaps of limited time for field work, the terrain of the country, and the fact that all computations were made in San Francisco, two hundred and fifty miles from the field work. These complications added difficulty to verifying any field errors.

To further check the triangulation and also make sure the chosen scheme for development was the best, an eighteen mile traverse line of four hundred and eighty courses was run down the McCloud River from Ah-di-na to Shasta Reservoir to be used as a control for further study and mapping. The angles were doubled and solar observations taken approximately every mile. The



T 39N
T 38N
River
McCloud
PILGRIM
LARK
FALLS
FOWLER
BIG
GRAVEL
U-2
U-1
GRIZZLY 1920
GRIZZLY LOOKOUT
STAR
STUMP CREEK
T-34
T-33
T-32
T-31
T-35
TAMARACK
T-39
T-40
T-37
T-36
T-38
T-41
T-42
AH-DI-NA
VAN SICKLIN
McCLOUD
SQUAW VALLEY
SVA
Valley
BALD MTN
Squaw
GAM
POINT GIRARD
NEAL
YELLOW JACKET

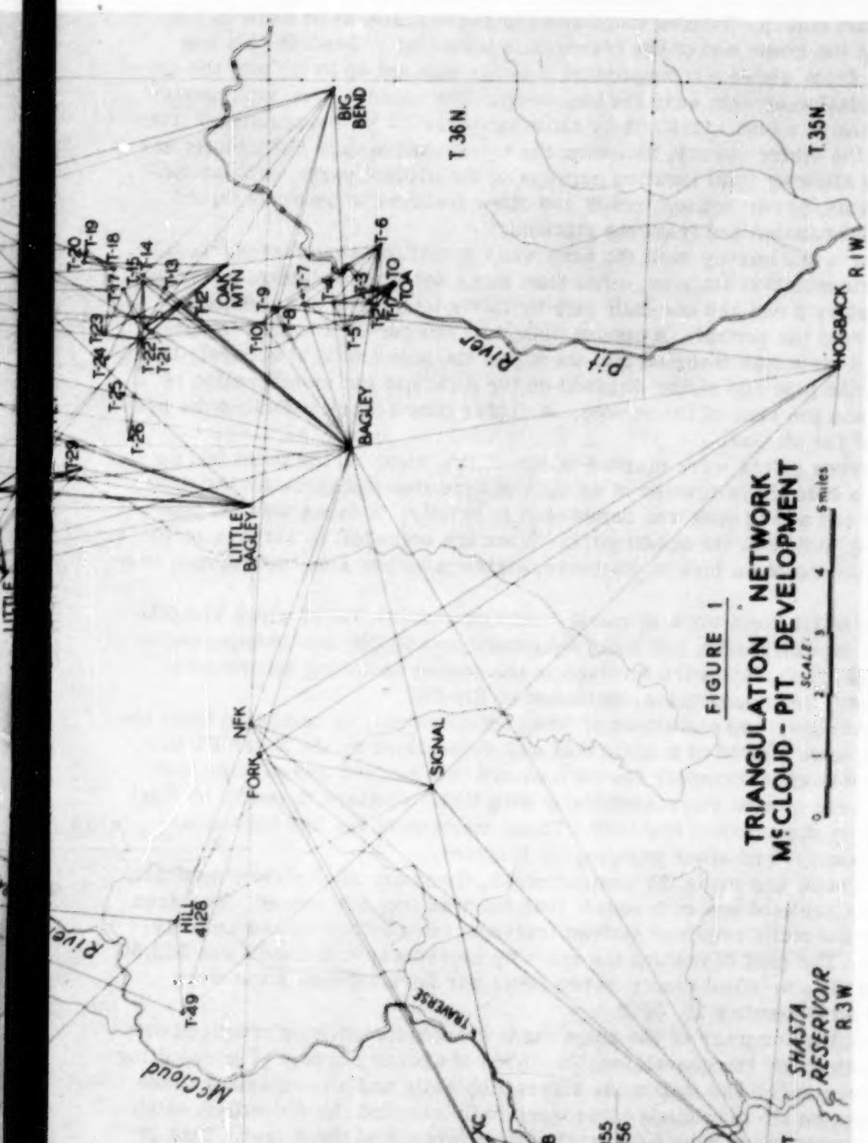



FIGURE 1
TRIANGULATION NETWORK
McCLOUD - PIT DEVELOPMENT

solars were adjusted for convergence of meridian to keep the entire survey on a plane rectangular coordinate system. Computed bearings were adjusted to the adjusted solars. Temperature and sag corrections were made to the chaining. At the lower end of the traverse, a base line of 1180.64 feet was established, from where a triangulation network was set up to tie into the original triangulation system near the beginning. The closure here was twenty-nine hundredths of a foot. (1180.64 by chaining—1180.93 by triangulation) This proved that the entire survey, including the triangulation, was sufficiently accurate, thus allowing final location surveys of the project parts, such as tunnel lines, dams, power houses, roads and other features to be made direct from the triangulation and traverse stations.

To preserve the survey until the time when actual location surveys would start, the triangulation stations, other than those set by government agencies, were marked by a one and one-half inch by thirty inch piece of galvanized pipe driven into the ground. A bronze disk, two and one-half inches in diameter with a stem was inserted into the top of the pipe and held securely by a pin through the pipe and stem. Scribed on the disk was the identification of the station and the year of the survey. A center punch mark indicated the precise point of the station.

The traverse points were marked in one of two ways. If the point fell on solid rock, a hole three-fourths of an inch in diameter and three inches deep was drilled and a lead plug was hammered in solidly. A cross was cut into the lead plug to denote the actual point. When the point fell in earth, a steel rod three-fourths of an inch in diameter, eighteen inches long, was driven into the ground.

The cost of the field work in round numbers was $95,000 of which $86,000 was for the survey parties and their equipment and $9,000 for transportation and packing. The office work involved in the survey including all computations, plotting, and supervision, amounted to $16,000.

The coordinates and elevations of the control points, as computed from the field notes, were plotted at a scale that was determined by the Kelsh Plotter. This scale was approximately one inch equals two hundred and seventy feet. The maps were plotted stereoscopically with Kelsh Plotters in pencil on Vynl because of its dimensional stability. These maps show ten foot contours, culture, drainage, and other topographic features.

After a check was made for completeness, the maps were photographically reduced to a scale of one inch equals four hundred feet and traced. The area covered by the maps required sixteen tracings, twenty-four inches by forty-two inches. The cost of making the maps by stereoscopic methods was $62.50 per square mile or about ninety-seven cents per acre. These maps were completed on December 15, 1953.

To check the accuracy of the maps made stereoscopically, a proposed damsite was mapped by the conventional methods of ground survey. The resulting map was overlaid on the map made stereoscopically and a comparison made. The contours on the map made stereoscopically checked the elevations established by the ground survey by a maximum difference of three feet. This is well within the one half contour interval limit generally prescribed for accuracy in aerial mapping.

Final layouts for the hydro-project were made using the new reliable maps as a base, and subsequently, in January, 1954, formal application was made to the Federal Power Commission to develop the McCloud-Pit Project. The main features of the project as applied for, consisted of three main reservoirs with a combined capacity of 168,000 acre feet of storage, three small

diversion reservoirs with negligible capacity, seventeen and one-half miles of tunnel which varies in diameter from fourteen feet to nineteen feet, and two power houses with combined generating capacity of 258,000 horsepower.

PROCEEDINGS-SEPARATES

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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c. Discussion of several papers, grouped by Divisions.

e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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